RESEARCH DEPARTMENT

THE EFFECT OF AN INTERLEAVED BAND III AERIAL ON THE PERFORMANCE OF A BAND II SLOT AERIAL

Report No. E-053

(1955/34)

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SUMMARY

Two tiers of four Band III batwings could be mounted on each tier of the Band II aerial at Sutton Coldfield without impairing its performance. The horizontal radiation pattern remains very uniform, though less so than formerly. The bandwidth is not degraded, although re-adjustment of the matching controls would be necessary.

1. INTRODUCTION.

It is proposed to provide a Band III aerial at Sutton Coldfield, and possibly at other high-power television stations, by mounting vertically-polarised tangential batwings in rings of four upon the existing cylindrical Band II aerial. This report describes a brief investigation into the effect of the Band III elements on the performance of the Band II aerial.

The Band II aerial, which is identical to that installed at Wrotham[1-3], consists of a cylinder 6 ft 6 in. (1·98 m) in diameter and 84 ft (25·6 m) long, divided into eight 10 ft 6 in. (3·2 m) sections, in each of which are cut four vertical slots. Two additional sections of the cylinder, provided above the aerial in order to accommodate the Band I diplexer, extend the total length to 105 ft (32 m).

It was originally intended to provide an eight-tier Band III aerial mounted on the diplexer sections and on the upper two sections of the Band II aerial. Since only one quarter of the Band II aerial would be affected, it was decided that any degradation in its performance could be accepted. It was later proposed to increase the number of tiers of the Band III aerial to sixteen, so that the Band III elements would be mounted either on the eight tiers of the Band II aerial, or on the diplexer sections and the upper six tiers of the Band II aerial. The former alternative would be preferred, since all eight tiers of the Band II aerial would be affected equally and there would therefore be no loss of gain.

In view of the proposal to use sixteen tiers it became clear that the effect of the Band III elements on the performance of the Band II aerial could no longer be ignored. Two effects required consideration: the change in the horizontal radiation pattern (h.r.p.) and the change in the impedance.

It was decided that Research Department should use a small-scale model to measure the h.r.p. in the presence of the Band III elements, leaving Planning & Installation Department to include the effect of the Band III elements when developing and matching the Band II feeder system at Aldenham. Nevertheless, it was considered desirable to use the small-scale model to determine at least the order of magnitude of the change in impedance due to the Band III elements, since the full-scale measurements would not be carried out for some time.

2. THE BAND III AERIAL.

The proposed Band III aerial, which is described in Research Department Report No. E-051[4], consists of vertically-polarised tangential batwing elements arranged in rings of four round the existing cylindrical Band II slot aerial. Two rings will be mounted on each section of the cylinder, at a vertical spacing of 5 ft 3 in. (1·6 m). Fig. 1* shows the elements and their arrangement on the slot aerial. It will be seen that the stubs forming the ends of the batwing slots are bent inwards and bonded to the face of the cylinder. This was done to prevent resonance at the Band II frequency, at which the length of each batwing is approximately one half-wavelength. Ideally each Band III element should have been placed

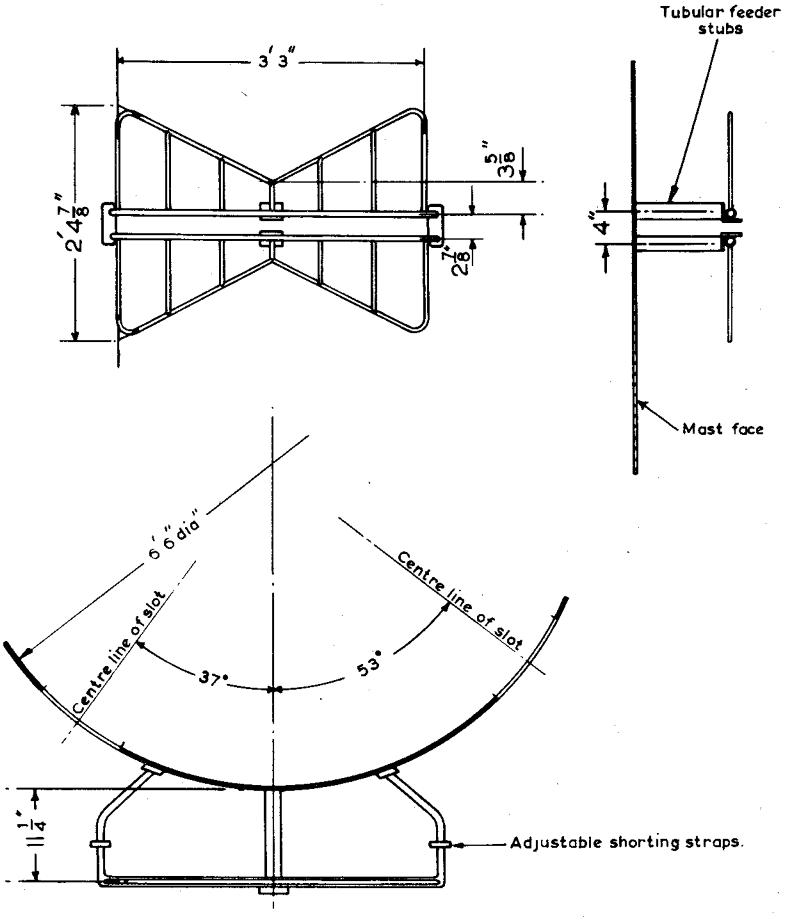

Fig. 1 - Proposed Band III batwing elements and their arrangement on the cylinder

midway between Band II slots of the same tier, but for mechanical reasons the elements were displaced by 8° from this position.

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*Based on Planning & Installation Department Drawing No. PID.SK.4962B.

The experiments were performed on an early single-tier model (scale factor 1/4·05) of the Band II slot aerial, consisting of a brass cylinder supported on a square-section steel lattice mast fitted with screening bars.

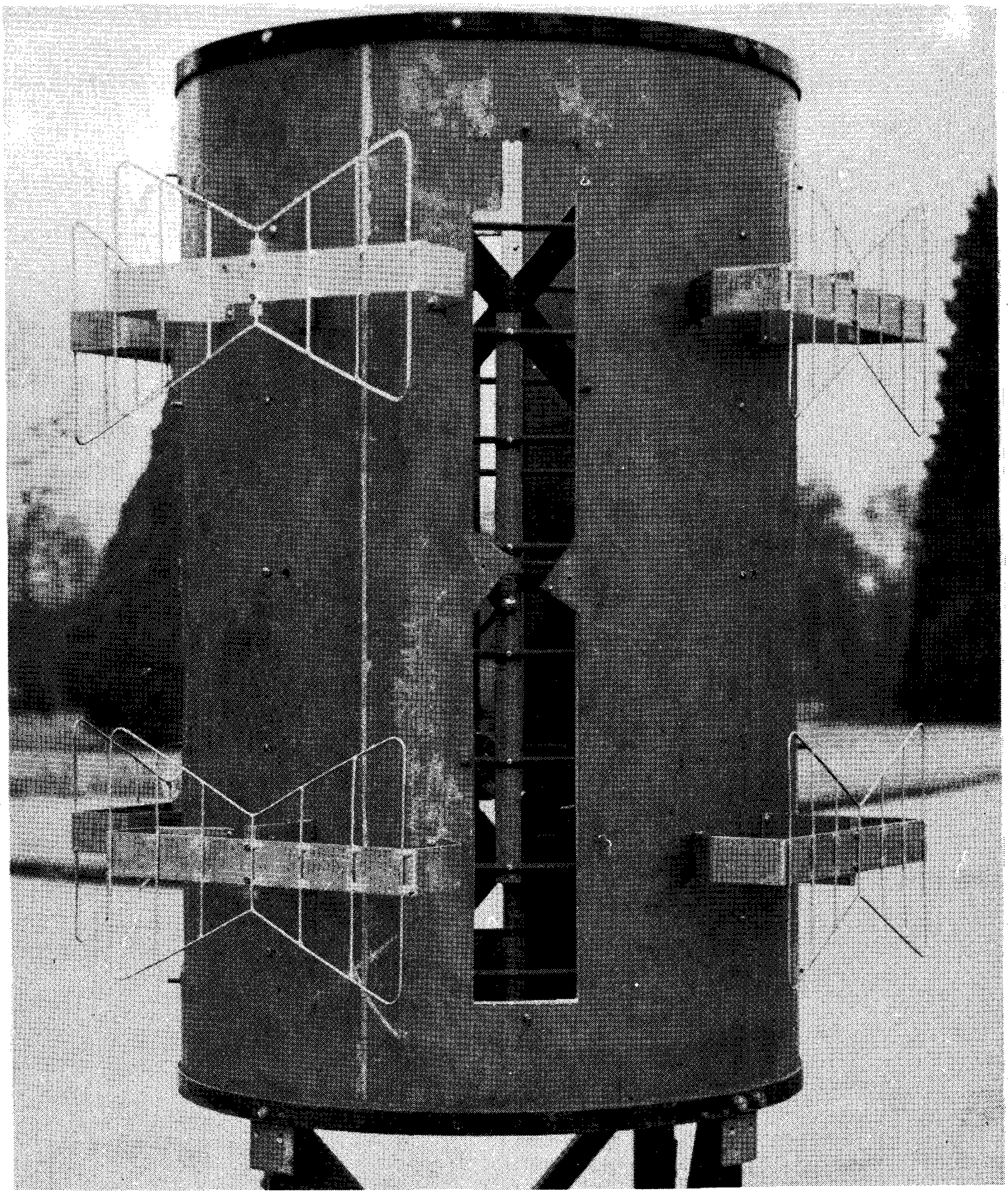


Fig. 2 - Model Band II slot aerial with model batwing elements

Since the Band II transmission will be horizontally polarised it was not necessary to simulate the separate tubes forming the slot and feeder stubs of each batwing element. Each model batwing therefore consisted of a tinned copper wire element soldered to a brass strip, a further brass strip being added at the centre to simulate the feeder stub. The width of each strip was equal to four times the geometric mean of the radius and centre spacing of the pair of tubes it represented; this was done to make its free-space capacitance and inductance approximately equal to that of the tubes. Fig. 2 shows two tiers of model elements mounted on the single-tier Band II model.

The slots of the model Band II aerial were fed in phase by driving one side of each slot, the cable outer being bonded at the centre of the screening bars as shown in Fig. 3. The four cables were combined in parallel inside the cylinder and connected to a feeder passing inside the lattice mast.

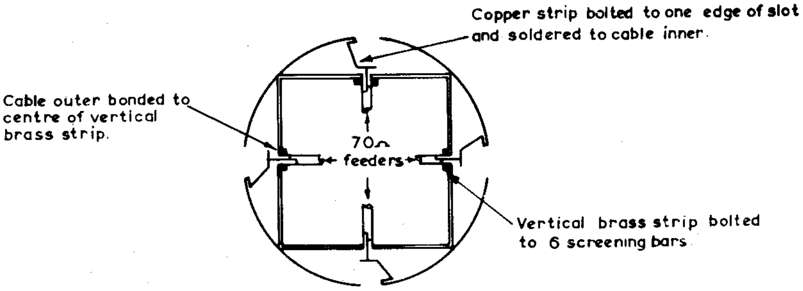

Copper strip bolted to one edge of slot and soldered to cable inner.
Cable outer bonded to centre of vertical brass strip.
70Ω feeders
Vertical brass strip bolted to 6 screening bars

Fig. 3 - Method of feeding slots

3. HORIZONTAL RADIATION PATTERNS.

All the radiation patterns were measured at 370 Mc/s, which corresponds to a full-scale Band II frequency of 91·5 Mc/s.

The h.r.p. of the Band II slot aerial measured in the absence of batwing elements is shown in Fig. 4. The shape of the pattern was found to be very sensitive to the mechanical and electrical symmetry of the model, and the slight asymmetry observed is ascribed to these two causes. The maximum/minimum ratio of the mean h.r.p. (obtained by taking the mean of field strengths which ought, by symmetry, to be equal) is 0·6 dB, a value in agreement with earlier measurements[1].

The h.r.p. measured with two complete tiers of batwings in position is shown in Fig. 5. The maximum/minimum ratio of the mean h.r.p. is 1·3 dB. It is possible that this figure may be slightly optimistic, since the process of distorting an h.r.p. by using an asymmetrical model, and then removing the asymmetry by averaging, tends to reduce the maximum/minimum ratio. By inspection of Fig. 5, the best estimate of maximum/minimum ratio is considered to be 1·6 dB. This is quite acceptable.

The h.r.p.'s of the Band II aerial measured in the presence of only one, two and three batwing elements in each of the two tiers are shown in Fig. 6. These results have no direct bearing on the work in hand, but the information may prove useful if a directional Band III aerial should ever be required.

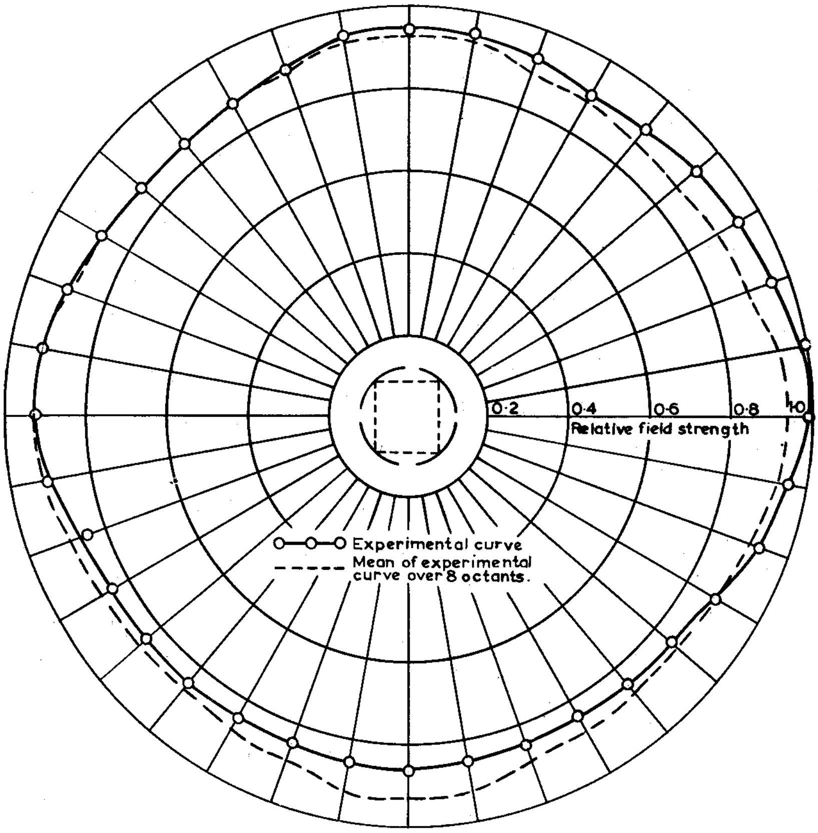


Fig. 4 - H.R.P. in the absence of Band III batwings

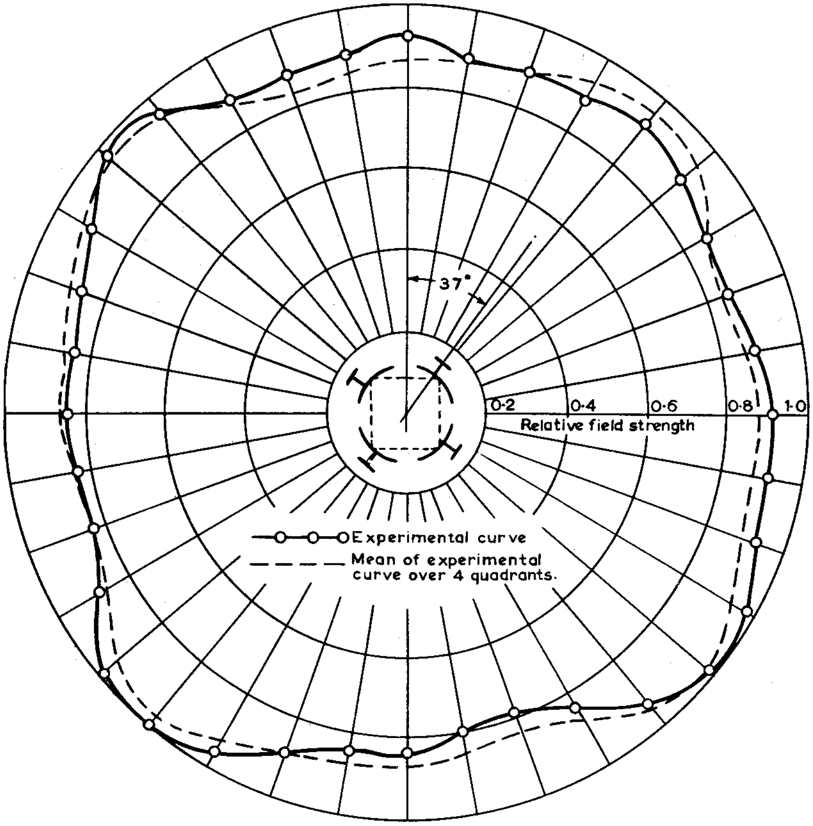


Fig. 5 - H.R.P. in the presence of 2 tiers of 4 batwing elements

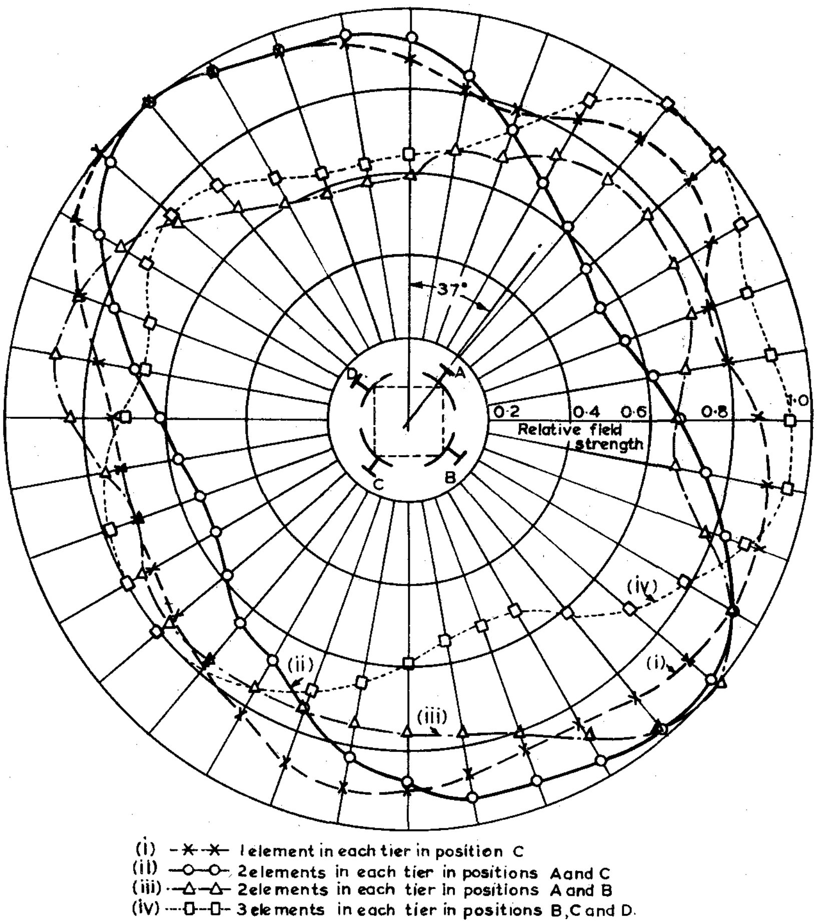


Fig. 6 - H.R.P. in the presence of 2 partial tiers of batwing elements

4. ADMITTANCE.

4.1. Measurement.

No attempt was made to match the aerial, or to simulate the method of feeding that will be used in practice. With the simple feeding arrangement shown in Fig. 3, a comparison method was used to determine that admittance which would have to be connected across the opposite edges of the slot to produce the same effect as the batwing elements. The Band II slots were fed from four equal lengths (25 cm) of thin 70-ohm cable (PT1M), connected to the slots as shown in Fig. 3 and combined in parallel inside the mast. A 3-metre length of larger 70-ohm cable (PT29MU) was used to connect this junction to the admittance meter.

Three sets of measurements were made, each at 5 Mc/s intervals, over the range 350-400 Mc/s (corresponding to 86·5-99 Mc/s at full scale). The admittance was measured firstly in the absence of the batwings, then with two tiers of batwings in position, and finally in the absence of the batwings but with a known capacitance introduced across each slot at its mid-point. The capacitances consisted of pairs of plates projecting from the cylinder; their value, measured at 10 kc/s on a jig simulating a Band II slot, was 0·19 pF.

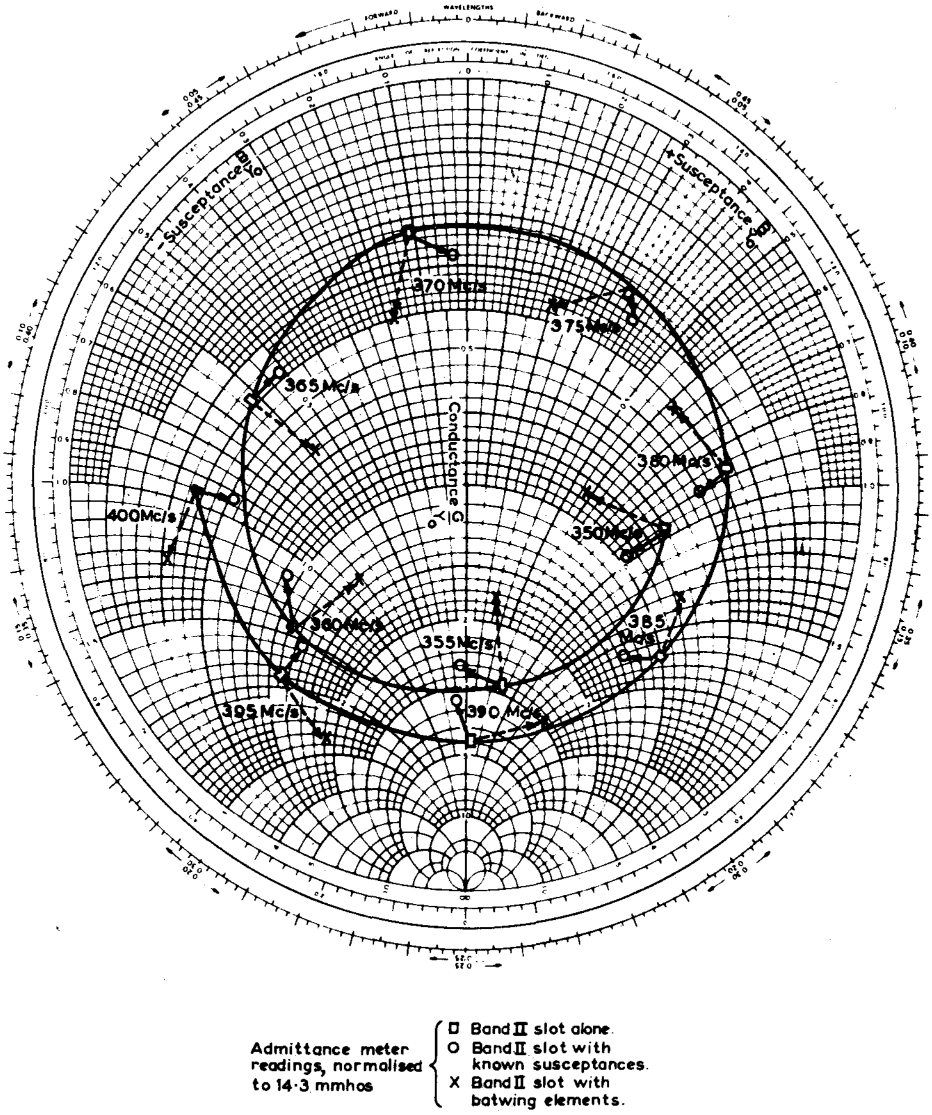


Fig. 7 - Change in Band II slot admittance due to adding either Band III batwings or known susceptance

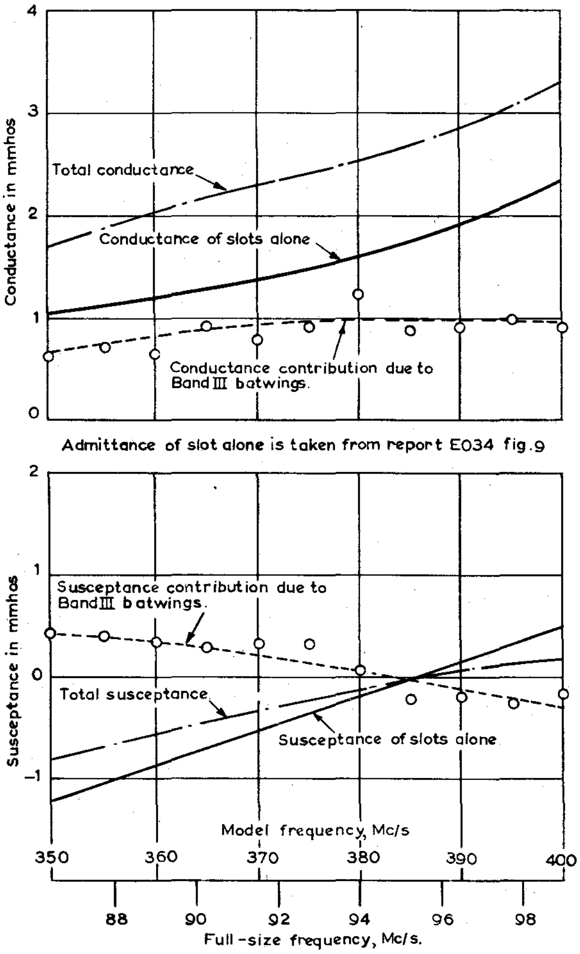
Fig. 7 shows the measured admittance taken directly from the scale of the admittance meter and normalised to 14·3 mmhos, without making any correction for the length of cable, or for discontinuities.

4.2. Interpretation of Results.

It is required to express the change resulting from the presence of the batwings as a change in the admittance of each slot referred to the mid-points of its edges. Let this change in admittance be ΔY_s and let the known susceptance introduced across the slot for calibration be $\Delta Y'_s$. In Fig. 7 the admittance meter readings are plotted on a Smith Chart, which is simply an Argand diagram of the reflection coefficient (relative to the 70-ohm cable used). Let the change in this reflection coefficient due to the batwings and to the known susceptance be $\Delta\rho_m$ and $\Delta\rho'_m$ respectively. It may be shown that if ΔY_s, $\Delta Y'_s$ were infinitesimal they would be related by the equation

$$\Delta Y_s = \Delta Y'_s \Delta\rho_m / \Delta\rho'_m \qquad (1)$$

This result follows from the fact that the admittance meter reading Y_m and the corresponding reflection coefficient ρ_m are analytic functions of the slot admittance Y_s. In fact ΔY_s and $\Delta Y'_s$ were not very small, but it is considered that the value of ΔY_s deduced from (1) will give at least an indication of the nature and the order of magnitude of the effect of the batwings.



Admittance of slot alone is taken from report E034 fig.9

Fig. 8 - Admittance of Band II slot aerial with and without interleaved Band III batwing elements

Referring to Fig. 7, the magnitude of $(\Delta\rho_m/\Delta\rho'_m)$ is the ratio of the length of the broken arrow to that of the full-line arrow, and its phase is the angle between these arrows. By obtaining $(\Delta\rho_m/\Delta\rho'_m)$ in this way and substituting in (1), taking Y'_s as the susceptance corresponding to 0·19 pF, ΔY_s was deduced. It is plotted as conductance and susceptance in Fig. 8 (broken curves). This figure also shows the effect of adding ΔY_s to the admittance measured on an early model of the slot aerial (taken from Reference 1, Fig. 9).

The real and imaginary parts of ΔY_s plotted in Fig. 8 are considered to be accurate to 0·4 mmho. The principal effects of adding the batwings are to increase the magnitude of the conductance and to decrease the susceptance slope. As a result, the bandwidth, in the absence of reactance compensation, is increased. In the folded-slot method of feeding used at Wrotham, which is to be repeated at future stations, the changes in conductance could be corrected by changing the spacing of the strip feeder. The reduction in susceptance slope might result in over-compensation of the input reactance, but this would not be sufficient to bring the admittance outside the specification[5]. In any case the compensation could be reduced by increasing the thickness of the vertical rod, and the admittance characteristic would then be better than at Wrotham.

5. CONCLUSION.

The addition of Band III batwings renders the h.r.p. of the Band II aerial slightly less uniform, but the maximum/minimum ratio is still only 1·6 dB.

Although the input admittance is affected appreciably, the change could be taken up on the controls. It is proposed that Planning & Installation Department should determine the necessary change in settings on a full-scale model during the development of the Band II feeder system. If steps were taken to reduce the reactance compensation the net result would be an improvement in bandwidth.

6. REFERENCES.

1. "Interim Report on FM Aerial for Wrotham and Sutton Coldfield", Research Department Report No. E-034, Serial No. 1948/19, July 1948.

2. "Second Interim Report on Wrotham FM Aerial and Sutton Coldfield Television Aerial", Research Department Report No. E-034/2, Serial No. 1948/36, November 1948.

3. "Final Report on Wrotham FM Aerial", Research Department Report No. E-034/3, Serial No. 1951/3, March 1951.

4. "Vertically-Polarised Band III Aerial for Sutton Coldfield", Research Department Report No. E-051, Serial No. 1955/29.

5. "The Specification of the Reflection Coefficient of a FM Aerial", Research Department Report No. E-048, Serial No. 1954/11, April 1954.